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The Legacy of Color Vision Testing in the Railway Industry

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Objective: To explore the methods and debate surrounding late nineteenth and early twentieth century railroad companies' screening of employees for colorblindness and the effect it had on subsequent testing by other industries and professions.

Methods: The author looked through issues of *The Railway Surgeon*, the official journal of the now-defunct National Association of Railway Surgeons, for articles on colorblindness and color vision testing as well as the 1905 edition of *Color Vision and Color-Blindness: A Manual for Railroad Surgeons*. Secondary literature on the subject was obtained via PubMed, MEDLINE, and other scholarly article databases.

Conclusions: Railroad medicine and the surgeons who practiced it influenced the study of colorblindness and set a precedent for occupational vision testing, a practice still in existence today.

Implications: If railroad medicine impacted color vision testing, it may have influenced other aspects of American medicine, especially occupational medicine.

The legacy of color vision testing in the railway industry

During the latter half of the nineteenth century and early half of the twentieth, railroad companies, and the surgeons they employed, discovered that colorblindness in front-line employees could lead to deadly accidents and put passengers at risk. In response, these surgeons developed and deployed numerous methods for detecting colorblindness, all with varying degrees of success. The most common of these methods was Holmgren's selection test using colored yarn. Railway surgeons and authorities debated the merits of each method as well as the necessity of testing itself and whether employees ought to be periodically re-examined. The sheer number of innovations and the discussion surrounding their use furthered the study of colorblindness and laid the groundwork for color vision testing in other fields and occupations.

As a result of the danger inherent in operating trains, many American railroad companies developed their own medical organizations and contracted with or hired physicians to care for their employees and customers during the latter half of the nineteenth century and the first decades of the twentieth [1]. As Mark Aldrich writes in "Train Wrecks to Typhoid Fever: The Development of Railroad Medicine Organizations, 1850 to World War I," these in-house medical organizations came into being "a generation before manufacturing companies showed any serious interest in such matters. Some organizations ministered to sick as well as injured employees, and delivered preventative medicine as well as emergency care to large numbers or working-class men and women" [1]. Color vision testing was one such service.

Railroad companies typically hired their own surgeons or contracted with physicians working along their routes (who either reported to the company's superintendent or a chief surgeon), although some companies built and staffed their own hospitals [1]. As the railroad industry grew and employed more workers, the number of physicians needed to care for these employees increased in turn. So much so that by World War I railroads employed about 10% of all United States physicians [2]. These doctors developed their own professional organizations and communicated about the concerns particular to their

trade including those involving their patients, their employers, and the public. Color blindness was a condition that could potentially impact all three constituent groups and was a topic of much discussion within the pages of *The Railway Surgeon*, the journal of the now-defunct National Association of Railway Surgeons.

Railroad companies needed to prevent accidents and protect their employees and passengers [1]. Since railroads relied on colored signals to direct trains, it was important that workers could distinguish between red, green, blue, and white. "A man who cannot name a red, green, blue or white signal the instant he sees it is not fit to run a train," states John Ellis Jennings, the author of *Color Vision and Color-Blindness: A Manual for Railroad Surgeons* [3]. In his book, Jennings describes the work of University of Edinburgh professor George Wilson who in 1854 "undertook the investigation of color-blindness from a practical stand-point" after discovering that several of his students were colorblind [3]. Wilson examined many colorblind individuals and deemed them "totally unfit" for a host of professions including that of dyer, chemist, physician, seaman, and railroad worker. Wilson was particularly concerned about "the dangers which threaten travel by rail and sea because of the peculiar liability of the color-blind to mistake the red (danger) and green (safety) signals in common use," writes Jennings [3]. Despite Wilson's worries, color vision testing did not become a common concern of physicians until the Lagerlunda accident in Sweden and the work of Frithiof Holmgren [3].

The origin of occupational testing for colorblindness is often ascribed to the fatal train crash that took place on a single-track stretch of railroad near Lagerlunda, Sweden in November 1875. Physiologist and professor Frithiof Holmgren believed that the accident was a result of undiagnosed colorblindness. After reviewing the particulars of the accident, Holmgren concluded that either the engineer or the oiler of the northbound express had been colorblind. Neither of the men survived the crash and therefore could not be tested for colorblindness [4]. Holmgren, however, wrote of his suspicion in a letter to the State Railroad Board in September of 1876 and in his 1877 book *Color-Blindness in its Relation to Accidents by Rail and Sea*. The Hanekinds Härads Rätt – the court that heard the Lagerlunda case – chiefly laid the blame on Uno Björkelund, the stationmaster at Linköping, where the two trains crossed paths [4].

Others have since reexamined the Lagerlunda collision and have argued that color blindness was not the primary cause of the accident – if it was a factor at all. In their article "The Lagerlunda Collision and the Introduction of Color Vision Testing," J.D. Mollon and L.R. Cavonius maintain that "if color deficiency contributed to the Lagerlunda collision, it was far from being the sole cause" [4]. Based on the evidence, they conclude that a "cascade of human errors," chiefly on the part of the stationmaster and his staff, most likely caused the accident. Mollon and Cavonius also suggest that heavy snowfall (which made the tracks more slippery), mechanical failure, and deficiencies in the signaling system cannot be ruled out as factors and may have played a part in the collision [4].

Moreover, Mollon and Cavonius argue that Holmgren, who had become interested in color blindness before the accident, used the Lagerlunda tragedy to promote the routine color vision testing of railroad employees. In July of 1876 Holmgren presented his method of screening for color blindness using colored yarn (which he had developed prior to the Lagerlunda collision) to a medical congress in Gothenburg, Sweden and seemed to receive a favorable response from the group [4]. He later arranged a demonstration of a test using colored lanterns for the general director of the State Railway Company, inviting two conductors he knew to be colorblind to serve as subjects. Holmgren employed this lantern test in cases where individuals had failed his yarn test. "The demonstration was rigged," write Mollon and Cavonius, "although not by bribing the conductors" [4]. Instead, Holmgren used a signal lantern with red glasses of different densities and another with green glasses of different densities to test his subjects. "The conductors were deceived because they were accustomed to judging colors by their luminosities" [4]. Holmgren's deception was ultimately successful, as the State Railway Company issued an order soon after the demonstration urging Swedish railway surgeons to "familiarize themselves with [his] method" [4]. Holmgren's yarn method was later widely adopted by British and American railroad companies and their surgeons.

The Illinois Central was the first American railroad to require visual examinations of its employees in the late 1870s, and several other railroad companies instituted similar requirements beginning in the 1880s. The Illinois Central may even been the first American company ever to test its

employees for color vision defects [1]. Moreover, several states (Connecticut, Massachusetts, Ohio, and Alabama) passed laws requiring railroads to test for colorblindness throughout the 1880s. Dr. B. Joy Jeffries of Massachusetts was a major advocate for the testing of railroad employees using Holmgren's method with colored yarn [1]. Employees objected to the tests, however, since many of the railroad men who were found to be colorblind through Holmgren's method had accident-free records. These men feared dismissal despite having performed their duties for years without incident.

Such fears may not have be entirely unwarranted. The topic of vision testing was brought up during a meeting between a "deputation of railway servants" and the general manager of the North-Eastern Railway (in Great Britain). This meeting is briefly summarized in the July 3, 1894 issue of *The Railway Surgeon*. "The men complain that the test is too severe, and is throwing good men out of employment, and they wish to have a practical test with signals substituted," writes the author. The general manager denied this request for a "practical" test because "they had the safety of the public to look after" [5]. Another physician writes in *The Railway Surgeon* that railway workers with an unrelated vision problem that could be alleviated by the use of corrective lenses nevertheless refrained from wearing them. Those seen wearing spectacles were often discharged for poor eyesight [6]. Although the employees' fears are understandable given this practice, failing to correct for more serious vision defects put the public at risk.

Railroads did sometimes deploy more "practical" tests that consisted of employees being asked to identify the colors of various railway flags and signals [7]. However, these sorts of practical tests were not always reliable. Jennings writes in his book that "this method seems so simple and so ample that it is often practiced even by the physician, and is the loop-hole through which many color-blind have escaped detection" [3]. Colorblind railroad workers often learned to compensate for their lack of color sense and, of course, knew what the colors of commonly used flags and signals were. To obtain accurate test results, physicians had to present their patients with the colors taken out of their occupational context. "There is quite a difference in looking at and handling worsted in the office that is clean, clear and distinct than a flag that is dirty and faded, and in the latter you often make your selection in double-quick time," writes

one physician of the potential pitfalls of using railway flags to test for color blindness [8]. Most railway surgeons relied on other, more dependable color vision tests.

Many other color vision test were developed in the last three decades of the nineteenth century and appear throughout *The Railway Surgeon's* run. "[P]robably at present there have been already some fifty methods or apparatuses devised for detecting chromatic defect, its character or amount," writes R. F. Harper of Ozark, AL in the June 27, 1899 issue [8]. Jennings argues that having all these tests is not "superfluous" as "experience has shown that the detection of color-blindness is difficult, and that, as we sometimes have cases of simulation to deal with, the examiner must be prepared to use a variety of tests" [3]. In his book, Jennings categorizes the various testing methods into four broad types: selection tests, lantern tests, pseudo-isochromatic tests, and contrast tests [3]. Selection tests involved patients choosing the correct colored object when asked and included Holmgren's yarn test. Railway surgeons sometimes used specially designed colored lanterns to test their patients, because this method more closely simulated color perception in real-life railroad work conditions [7]. Pseudo-isochromatic tests made use of "confusion colors" – colors that colorblind individuals had trouble distinguishing – and included tests using printed plates, powders, and woven patterns. Contrast tests involved colored shadows or tissue paper [3]. Selection and lantern tests appear most often in articles on colorblindness within *The Railway Surgeon.*

Holmgren's method in particular enjoyed widespread adoption. It was "the surest and quickest manner" of screening employees and fairly inexpensive at that, requiring only bits of colored yarn [8]. Harper writes that Holmgren's test is the method that "least taxes…the examiner" [8]. Dr. D. Emmett Welsh of the Grand Rapids and Indiana Railroad Company describes his use of Holmgren's method in an article for *The Railway Surgeon*: "a skein of yarn from the pile of worsted is shown [the patient], which is green, and he is told to pick out of the pile of worsted any color that looks like the one shown, either lighter or darker, or any color having a resemblance to it" [9]. If the patient could correctly select the skein of the named color, he passed. Holmgren's method did have its critics and some surgeons only used it for initial screenings; if the surgeon suspected colorblindness, he administered another type of test [9].

Another popular selection test was “Thompson’s stick” [3]. In response to Harper, Dr. William H. Elliot describes a stick with forty colors attached to it that had been “prepared by the oculist of the Pennsylvania Road” [8]. Although he does not describe this method in great detail, Elliot implies that it did not deviate much from Holmgren’s yarn test. Welsh [9] and Jennings [3] provide more detailed accounts of this test and credit Dr. William Thompson of Philadelphia for its invention:

> The instrument consists of two narrow, flat sticks, hinged together at one end and fastened by a catch at the other. The inside stick contains a row of forty hooks, to which are attached by bangles forty test skeins, arranged to be alternately match and con fusion colors. The bangles are numbered in such a way that odd numbers denote match skeins, and even numbers confusion skeins. [3]

The examiner would hand the patient a sample and ask him to choose ten matching tints from those on the stick. The result was then recorded using the numbers on the stick’s skeins [3, 9]. The great advantage of this method, Elliot insists, is that the numbering system allowed for the easy recording of test results [8]. Surgeons could send relatively inexperienced examiners out to test employees without worrying that these examiners might misinterpret the results [3]. If a worker failed Thompson’s stick test, then the surgeon himself would examine him more thoroughly [1].

Surgeons sometimes used other selection tests either singly or in combination with Holmgren’s method. Harper, for example, advocates the use of colored glasses of varying hues to test railroad workers. The author assures readers that the colorblind patient would “soon expose himself” if the examiner could shift the colored lenses in quick succession over the patient’s eyes [8]. Welsh describes using roses to test his patients after they had completed Holmgren’s test: “Then a rose is shown to him, when he is told to pick out any color – that or lighter” [9]. Although both of these test were simple to administer, they may have led to less accurate results.

Lantern tests performed under “standard and controlled conditions simulating actual signals” were at once more practical than using colored yarn but more dependable than tests requiring workers to correctly identify actual railway flags and signals [7]. Several alternative lantern tests were in use at the time [3]. One such lantern was known as William’s Lantern. This lantern was square and “about a foot high and six inches on each face. On its front [was] a single disc with eighteen colored glasses, and within

the lantern [were] two lights and a shutter, so arranged that either one or two of the colored glasses [could] be illuminated at one time" [3]. The test would take place in a darkened room with the lantern positioned about twenty feet in front of the patient. While the examiner switched the lights out using the sliding shutter, the patient named the colors as he saw them [3]. The examiner could present the patient with two shades of the same color at once (light red and dark red, for example). Colorblind individuals would often mistake these for two entirely different colors [3]. Jennings reports encountering patients "who passed the Holmgren test without difficulty, but who made so many mistakes with the reds and greens of the lantern as to show that they were unable to distinguish correctly the true colors of signal lights seen at the usual distances" [3].

British ophthalmologist Edridge-Green developed another specially-designed lantern in the late 1880s for the merchant navy. The Edridge-Green Lantern was later adopted by the British Navy (in 1909), the United States Navy, and several railroad companies [7]. "The Edridge-Green lantern provid[ed] a complex test presenting eight colors, with a choice of five or seven apertures…with neutral density filters to vary the signal intensity and ribbed and frosted glasses to simulate fog and rain respectively" write Barry L. Cole and Algis J. Vingrys in their 1982 article "A Survey and Evaluation of Lantern Test and Color Vision" [7]. The pair also note that despite enjoying widespread use, Eldridge-Green's test was too complex and lacked standardization data and therefore could not supplant Holmgren's method in the offices of many railway surgeons [7]. Nevertheless, the popularity of lantern tests is enduring; some railroad companies used lantern tests of one form or another up until the early 2000s [10].

Stilling's plates are an example of the third type of test for colorblindness, pseudo-isochromatic tests. Since colorblind individuals look for differences in the tint and intensity of light in colors to correctly identify them, Stilling worked with two colorblind individuals – one a painter and the other a teacher – to identify those colors "which appear identical not only in tint, but also in intensity of light" [3]. Stilling's invention consisted of "ten plates, each plate containing four squares, and arranged in such a manner that the squares of one color form letters and figures and those of the confusion color the

groundwork" [3]. The examiner would present these plates to the patient in a well-lit room and ask him to describe the letters and figures. Jennings recommends that railway surgeons use Stilling's test in conjunction with Holmgren's yarn test [3].

Mauthner's powders and Donder's patterns were two other pseudo-isochromatic tests used by railway surgeons. Mauthner's test involved thirty-four little vials of powders in various colors. Many of these bottles consisted of layers of either two different shades of the same color or two different colors entirely. The patient had to divide the vials into two groupings: the bottles containing two different shades of the same color on one side and the bottles with powders of differing colors on the other [3]. Donder's test, on the other hand, consisted of skeins in two "confusion colors" wrapped around a piece of wood and wound into a striped pattern. The patient was asked to count the different colored stripes. Colorblind individuals were not able to distinguish the contrasting skeins from one another [3].

Jennings describes a few different simultaneous contrast tests in his book such as a test involving shadows and two others involving colored tissue paper. If a white and a colored light are both directed at a colorless surface and an object is placed between the lights and the surface, then this object will cast two different shadows, one the color of the colored light and the other in its complimentary color. A red light, for instance, will cast both a red and a green shadow. A colorblind person would only see a gray or black shadow [3]. For the two tissue paper tests Jennings writes about, Meyer's and Pflueger's, the examiner lays a piece of tissue paper atop a sheet of colored paper with black or gray borders or letters. The borders or letters will appear in the color complimentary to that of the sheet of paper as a whole. If a colorblind individual could make out the background color, he would not be able to distinguish its compliment [3].

Tests and contraptions for screening out colorblind individuals that did not fall under any of Jennings' groupings abounded. Welsh mentions one such contraption that simulated the fixed railway signal known as the semaphore. Welsh turned to the semaphore if a patient failed Holmgren's test, the colored rose test, Thompson's stick test, and a light test [9]. Although Welsh does not describe the semaphore in detail, he does provide an illustration of it. The device consists of a pole on a stand with an arm attached on either side at different heights. Hanging on these arms are little moveable squares with

circles of colored Venetian glass within them. A little circular opening adorns the end of each arm, over which the squares can be placed [9]. Since this semaphore presumably worked like its counterpart on the tracks, Welsh likely illuminated the glass-covered openings with a lamp or some other source of light. Welsh writes that he would display two confusion colors at either end of the semaphore and ask the patient to name them both [9].

Railway surgeons not only disagreed about preferred screening methods; some even questioned the necessity of testing altogether. These surgeons expressed skepticism at the reported number of accidents attributed to colorblindness [11]. "What need anyone care if a railway employee is competent to interpret the various elements of danger whether he can undergo Holmgren's test or not? If the various elements of warning are properly interpreted, it is immaterial whether he is competent to teal the various gradations of color," asks an author identified only as "N. A. R. S" (but who may have been one of the National Association's board members or the journal's editor) [11]. An ability to match colored pieces of yarn does not prove anything, N. A. R. S. argues, as many other factors involved in conducting a train or managing a line can impact safety [11]. N. A. R. S. later asserts that he has personally cataloged the histories of thirty thousand railway accidents and has yet to come across a single instance in which colorblindness was shown to have caused the accident [11]. Other surgeons discussed how to distinguish the colorblind from the "color ignorant" – those who could see different colors but who could not name and differentiate the various hues [12]. "I find, using Holmgren's tests, that ten men are color ignorant where one man is color blind," says one surgeon [12]. This surgeon also attributes the reported higher incidence of color blindness in men to color ignorance. More men were color ignorant because boys were not taught colors to the extent girls were [12].

Railway surgeons also debated when in the hiring process colorblindness testing was most appropriate and how often they ought to re-test workers. Many wished to make the screening process fairer to railroad employees, particularly those who had had long accident-free work histories. "Color tests, as applied in many instances, partake of gross injustice," writes N. A. R. S. [11]. Competent employees are let go "capriciously," he says, because they fail Holmgren's test. Another surgeon writes

that screening at the time of hire was of utmost importance, because the injustice lay not in the screening out of would-be colorblind employees but rather in the dismissal of loyal workers with years of service. Standards would ensure that these men did not "[waste their] time in learning a business they may have to abandon." However, this surgeon argues that a single industry-wide standard "will not answer" as better vision is more "necessary on the head end of a train than would suffice for switchmen" [12]. Some surgeons believed that employees' vision, including color perception, should be periodically re-examined, and that those employees who had defects should either be replaced be younger, fresher workers or assigned other, less risky tasks [13, 14]. While Welsh believed that color vision testing was absolutely necessary, he also felt that after an initial diagnosis had been made subsequent tests were superfluous [14]. Welsh does, however, describe using several different testing methods in his initial screening process [9]. Other surgeons may not have been so thorough.

Use of color vision tests by ships' doctors and physicians who cared for mariners may have inspired the push to screen railway employees for colorblindness as well. The two branches of occupational medicine had similar missions. Mark Aldrich speculates that "the idea for a company surgeon was inspired by the naval example of carrying a ship's surgeon, for early railroading was dangerous and many of these early lines went through wild and sparsely settled regions, as far from physicians as ships were from seaports" [1]. Evidence of a connection appears in the October 8, 1895 issue of *The Railway Surgeon*, specifically within a reprint of a letter to the editors of *Lancet* entitled "Defects of Visions and Accidents." The author is a British surgeon by the name of R.A. Caldwell who claims to have been a surgeon aboard a steamer called The Russia in the year 1890 [15]. At one point, the ship took on a new crew member who, during his initial physical with the author, exhibited symptoms of a color vision defect. This inspired the author to test the entire crew for vision defects that day and to have those he diagnosed with such defects relieved from lookout duty. That very night, he reports, there was a near-collision with a passing ship. The author insinuates that The Russia would have collided with that other ship had those crew members with vision defects been on lookout duty [15]. Other reports of

shipwrecks and accidents attributed to colorblindness furthered railway surgeons' case for color vision testing [16].

Railroad companies' widespread adoption of color vision testing encouraged the practice in other industries. With the advent of the automobile, the railroad industry no longer dominated the transportation market. Moreover, corporate involvement in health care fell out of favor during the Great Depression, and the practice of railway surgery slowly shrunk as a result [2]. The National Association of Railway Surgeons broadened their scope to industrial surgery as a whole and *The Railway Surgeon* became the *Surgical Journal Devoted to Traumatic and Industrial Surgery* in 1921 [2]. Nevertheless, railroad companies continued to screen for colorblindness [10], and railway surgeons' exploration of colorblindness and color vision testing laid the groundwork for testing in other related fields. Commercial airline pilots and professional flight crews, for instance, must undergo color vision tests, as they need to be able to distinguish red and white lights on a landing strip. The industry originally used a lantern test similar to those used by railroad companies when the need to distinguish colored lights became a requirement in 1919 [17]. Within the transportation industry as a whole, the debate surrounding the necessity and appropriateness of screening employees for colorblindness persisted in one form or another until at least the late 1980s [18]. Two major transport accidents in recent history, one in New Jersey in 1996 and another in Tallahassee airport in 2002, led, in part, to a review of color vision examination methods by the international community [17].

Nineteenth century physicians developed many different methods and tools for detecting colorblindness in railroad workers to ensure the safety of the public after a major accident in Sweden alerted them to its possible dangers. Railroad companies had to protect their passengers while retaining an experienced, well-trained, and competent workforce, which often caused some tension for officials. The result of this conflict, however, laid the foundation for the policies surrounding occupational screening for colorblindness in existence today. Although their profession has long been forgotten, railway surgeons have had a lasting impact on occupational health and industrial medicine in the United States, particularly with regards to our understanding of colorblindness. Further examination of the profession's journals,

particularly *The Railway Surgeon*, may unearth their influence on other modern-day medical policies and practices.

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